Set 32.0: Kinetic Theory of Gases

Skill 32.01: Describe an ideal gas
Skill 32.02: Compare the rates of effusion and diffusion for different gases
Skill 32.03: Describe the conditions under which a gas will deviate from ideal behavior

Skill 32.01: Describe an ideal gas

Skill 32.01 Concepts

The word kinetic comes from the Greek word kinetikos, which means "moving". The kinetic theory of matter is based on the idea that particles of matter are always moving and can be used to explain the properties of gases, liquids, and solids.

An ideal gas is an imaginary gas that conforms perfectly to the following assumptions:

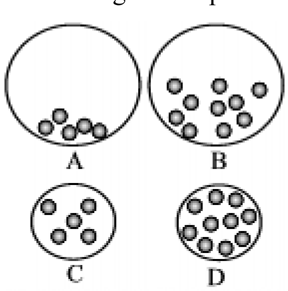
(1) Gases consist of large numbers of tiny particles. The size of the particles which make up the gases are insignificant compared to the distance between the particles.
(2) The particles of a gas are in constant motion, that is they posses kinetic energy
(3) The collisions between the particles of a gas are elastic, that is there is no loss in energy.
(4) There are no forces of attraction or repulsion between the particles of a gas
(5) The average kinetic energy of the particles of a gas is directly proportional to its temperature, ONLY
(6) The speed at which a gas particle travels is inversely proportional to the square of its molecular mass. Small gas particles travel faster than large gas particles.

Although ideal gases do not actually exist, the behavior of many gases conforms to the assumptions above at very high temperatures and very low pressures.

Skill 32.01 Problem 1

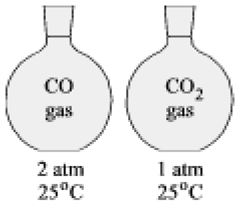
(a) Compare the kinetic energy of NH_3 to HCl at 25ºC. (b) Compare the velocities of NH_3 to HCl at 25ºC.

Skill 32.01 Problem 2

Consider the following diagrams representing different "gas" samples.  Which gas would behave most like an ideal gas? Explain.	

Skill 32.01 Problem 3

Samples of $CO(g)$ and $CO_2(g)$ are placed in 1 L containers at the conditions indicated in the diagram.

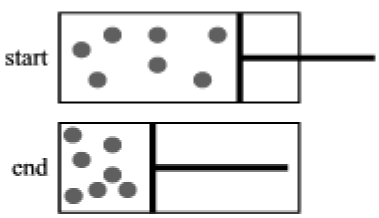


(a) Indicate whether the average kinetic energy of the $CO_2(g)$ molecules is greater than, equal to, or less than the average kinetic energy of the $CO(g)$ molecules. Justify your answer.

(b) Indicate whether the average speed of the $CO_2(g)$ molecules is greater than, equal to, or less than the average speed of the $CO(g)$ molecules. Justify your answer.

Skill 32.01 Problem 4

1. An ideal gas at 25ºC was compressed at constant temperature as shown below. Explain the effects, if any, on each of the following:



(a) The kinetic energy of the molecules
(b) The speed of the molecules
(c) The density of the molecules

Skill 32.02: Compare the rates of effusion and diffusion for different gases

Skill 32.02 Concepts

Effusion is the term used to describe the passage of a gas through a tiny hole. The rate of effusion is inversely proportional to the square root of the mass of its particles. Unlike the kinetic energy, effusion DOES depend on the size of the molecule: the bigger the molecule, the slower it effuses, and vice versa. Table 1 summarizes this fact.

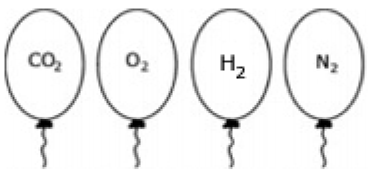
Table 1. Comparison of effusion rates, and diffusion rates and kinetic energy

Molecule	H_2	CH_4	CO_2
Mass (g/mol)	2.016	16.04	44.01
Kinetic energy (J/molecule)	6.213×10^{-21}	6.213×10^{-21}	6.213×10^{-21}
Rate of effusion (m/s)	1,926	683.8	412.4
Rate of diffusion (m/s)	1,926	683.8	412.4

Diffusion is the term used to describe how quickly two gases will mix. Like effusion, the rate at which a molecule diffuses is also dependent on the size of the molecule: the bigger the molecule, the slower it diffuses, and vice versa. This fact is also summarized in table 1.

Skill 32.02 Problem 1

The balloons shown have identical volumes and are under the same conditions of temperature and pressure. Each balloon contains the same number of



(a) Compare the kinetic energy of the molecules in each balloon. Explain.
(b) If a pin-hole sized leaked developed in each balloon, which balloon would be the smallest after minutes? Explain
(c) If each balloon was popped with a pin, the molecules in which balloon would diffuse most quickly? Explain.

Skill 32.03: Describe the conditions under which a gas will deviate from ideal behavior

Skill 32.03 Concepts

In 1873 Johannes van der Waals proposed that real gases *deviate* from ideal behavior because (1) particles of real gases occupy space and (2) particles of real gases exert attractive forces on each other.

In general, gases that most closely obey ideal behavior are

(1) small
(2) nonpolar (are symmetrical)
(3) exist at high temperature and low pressure

Skill 32.03 Problem 1

Under which conditions will helium gas behave most ideally? Explain. (a) 100 K and 1 atm (b) 200 K and 2 atm (c) 0 K and 0.5 atm (d) 200 K and .5 atm	Under which conditions will helium gas deviate the most from ideal behavior? Explain. (a) 100 K and 1 atm (b) 200 K and 2 atm (c) 0 K and 2.0 atm (d) 200 K and .5 atm

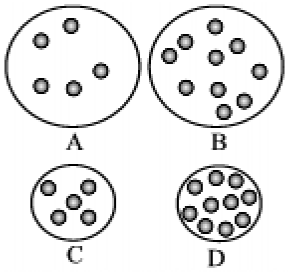
Skill 32.03 Problem 2

Which of the following (nonpolar) gases below will behave most ideally? Least ideally at STP? CO_2, H_2, Ar, N_2, O_2, C_2H_6

Skill 32.03 Problem 3

(a) Classify each molecule as polar or nonpolar (b) Which molecule will deviate the most from ideal behavior? The least? Explain. CO_2, H_2O, NH_3, Ar, He, H_2S

Skill 32.03 Problem 4

Consider the following diagrams representing different gas samples all at the same temperature.  Which gas would deviate most from ideal behavior?